A new staged hybrid total arch repair procedure using a branched proximal elephant trunk technique with implantation of stent grafts to the ascending aorta

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We report a new hybrid aortic arch repair procedure for the treatment of extensive thoracic aortic aneurysms involving the ascending aorta, arch, and descending aorta. In the first stage of this procedure, a "double-barrel tube graft" was inserted into the ascending aorta and fixed to the sinotubular junction under short-duration cardiopulmonary bypass in normothermia. In the next stage, after debranching of the left common carotid artery and left subclavian artery, stent grafts were deployed from the double-barrel tube graft to the descending aorta and the brachiocephalic artery to exclude the aneurysms. The patient's postoperative course was uneventful, with no endoleaks. The successful initial result suggests that this procedure could be an attractive treatment option for extensive aortic aneurysms. (J Vasc Surg 2013;58:1700-4.)

Direct surgical treatment of extensive aortic aneurysms that involve the ascending, arch, and descending segments still remains challenging. Several operative techniques to accomplish extended total arch replacement have been described, including one-stage and two-stage repairs. Although the conventional surgical methods have been improved, this approach is still associated with considerable in-hospital (7.2%-16%) and 30-day (5.0%-6.6%) mortality.[1-4]

Meanwhile, hybrid aortic arch repair procedures using stent grafts have emerged as an attractive alternative option, and satisfactory results have been reported in comparison with the conventional open surgery. According to the systematic review of hybrid aortic arch repairs published in 2012 by Cao et al,[5] perioperative mortality was 2.0% to 11.9% in the debranching group, 1.7% to 18.2% in the frozen elephant trunk group, and 1.6% to 25% in the stented elephant trunk group. Moreover, Milewski et al[3] reported that in-hospital mortality was much better in the patients aged >75 years, at 8% for hybrid arch repair vs 36% for conventional open surgery. These procedures could therefore be a promising less invasive treatment for the higher-risk patients.

However, these hybrid procedures still require the replacement of the ascending aorta when a concomitant ascending aortic aneurysm exists in order to create a sufficient proximal landing zone to fix the device and seal off the blood flow from the aneurysm. Therefore, cardiopulmonary bypass (CPB) with cerebral protection is still required, including deep hypothermic circulatory arrest (DHCA), which constitutes a risk factor for mortality or morbidity, particularly in high-risk patients. Immer et al[6] reported from a cohort who underwent resection of the ascending aorta that neurologic events were observed much more frequently in the group treated with DHCA (11.7%) than in those without (2.7%), whereas Patel et al[4] reported that prolonged lower circulatory arrest time is one of the independent predictors of death.

In this report we describe a new hybrid procedure in which a sufficient proximal landing zone can be achieved by simply inserting a "double-barrel tube graft (DBG)" into the ascending aorta.

CASE REPORT

A 79-year-old woman who complained of hoarseness was diagnosed with thoracic aortic aneurysms and was referred to our hospital. A computed tomography scan showed an extensive aortic aneurysm with an ascending aortic diameter of 50 mm and a distal arch aortic diameter of 70 mm (Fig 1). The sinotubular junction and the sinus of Valsalva were normal, and the aortic valve was tricuspid, without regurgitation. Because there was no sufficient

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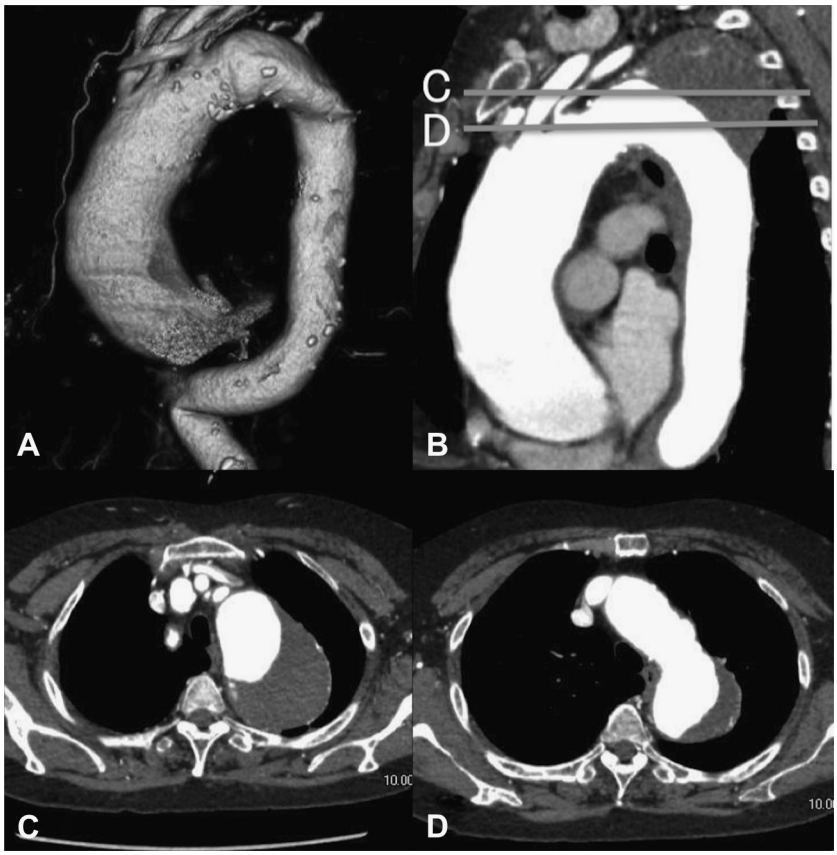

Fig 1. The preoperative computed tomography angiogram revealed an extended aortic arch aneurysm with an ascending aortic diameter of 50 mm and a distal arch aortic diameter of 70 mm. **A,** A three-dimensional reconstruction image. **B,** Sagittal view shows the aortic arch. Axial views are shown at the **(C)** level of the maximum aortic diameter and at the **(D)** level of the aortic arch.

landing site in zones 0, 1, and 2, it was difficult to treat this patient by thoracic endovascular aneurysm repair with a debranching procedure. However, conventional surgery was considered to be a high-risk option because of the patient's advanced age and poor physical condition; accordingly, a less invasive hybrid procedure was planned.

In a patient like this, with an ascending aortic aneurysm, graft replacement of the ascending aorta would usually be required because the proximal management part of a hybrid procedure, in which DHCA would be needed, would be unavoidable to create an open distal aortic anastomosis. However, clamping of the ascending aorta was considered to be feasible given the absence of mural thrombosis or calcification. We therefore planned to implant a DBG, which would serve as the proximal landing zone for subsequent endovascular repair using stent grafts.

Description of device. The DBG (Fig 2) was composed of a ringed Gore-Tex 12-mm (W. L. Gore & Associates, Flagstaff, Ariz) as the branch graft and a 28-mm Triplex graft (Vascutek Terumo, Tokyo, Japan) made of Dacron (DuPont, Wilmington, Del) as the main graft, which were designed to be used as the proximal landing platform of the stent graft bridging to the brachiocephalic artery and the descending aorta. These two grafts were

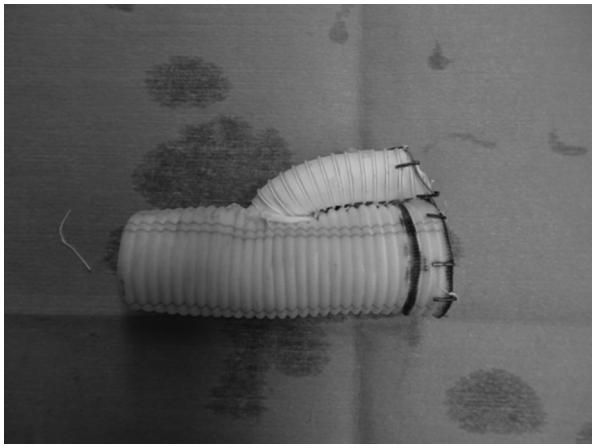

Fig 2. A double-barrel tube graft was made of two graft components: a ringed Gore-Tex 12-mm graft (W. L. Gore & Associates) was used for the branch graft and a 28-mm Triplex graft (Vascutek Terumo) made of Dacron (DuPont) was used for the main graft. Radiopaque markers were placed at the distal rim of each graft and at the bifurcation.

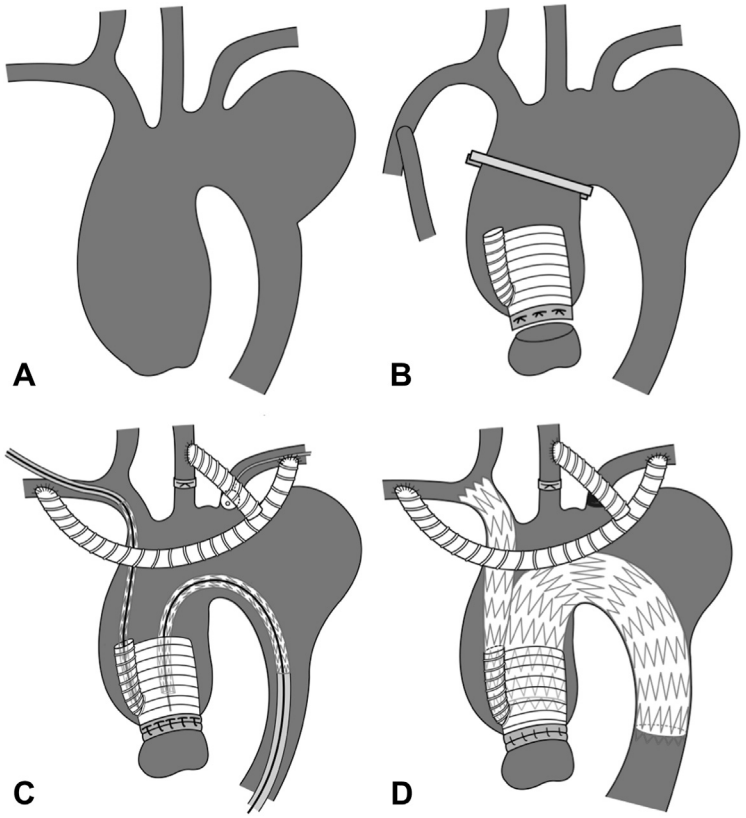

Fig 3. Diagrams show the procedure. **A,** An aortic aneurysm extends from the ascending aorta to the descending aorta. **B,** The double-barreled tube graft is inserted into the ascending aorta. **C,** The right subclavian artery is connected to the left common carotid artery and the left subclavian artery with a ringed Gore-Tex 8-mm bifurcated graft (W. L. Gore & Associates). **D,** Stent grafting from the double-barreled tube graft to the descending aorta and brachiocephalic artery.

chosen because of their durability against the compression and kinking force, which would help preserve their integrity within the ascending aorta. Both tubes had a free length of 4 cm from the bifurcation that would serve as the landing zone for stent graft insertion.

Operation. Through a median sternotomy, the brachiocephalic artery and the ascending aorta were exposed. CPB was established with right axillary perfusion under normothermia. After the ascending aorta was cross-clamped just proximal to the brachiocephalic artery, the ascending aorta was transected just distal to the sinotubular junction. The DBG was inserted into the ascending aorta, oriented with the branch graft directed toward the brachiocephalic artery (Fig 3, *B*). The proximal end of the DBG was sutured to the distal end of the transected aorta around the whole circumference, with a felt strip outer surface for reinforcement. Subsequently, this distal stump and proximal end of the transected aorta were resutured around the entire circumference. The aorta was declamped after the air and debris had been eliminated. The CPB time was 65 minutes and cross-clamp time was 36 minutes. After hemostasis and sternal closure had been achieved, the patient was admitted to the intensive care unit.

The following day, a debranching procedure and endovascular repair were performed under general anesthesia. First, bypass grafting from the right subclavian artery (RSCA) to the left common

Fig 4. Intraoperative angiography revealed good blood flow into the brachiocephalic artery through the branch graft. The extended aortic aneurysms were completely excluded from the circulation.

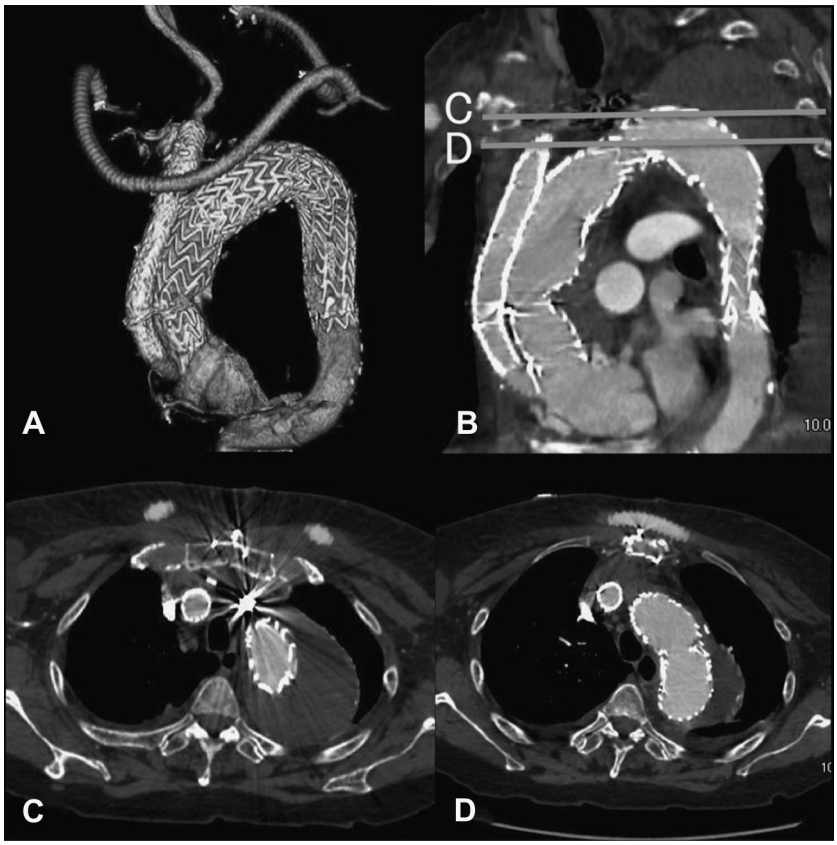

Fig 5. The postoperative computed tomography angiogram revealed well-preserved cervical bypass flows and complete exclusion of the aortic aneurysms, with no endoleak. **A,** A three-dimensional reconstruction image. **B,** Sagittal view of the aortic arch. Axial views are shown **(C)** at the level of maximum aortic diameter and **(D)** at the level of the aortic arch.

carotid artery and subclavian artery were performed using a ringed Gore-Tex 8-mm bifurcated graft (Fig 3, *C*). Next, Lunderquist wires were placed into each lumen of the DBG through 8F sheaths inserted to both the right femoral artery and the RSCA. After that, a 20F Keller-Timmermanns Introducer Sheath (Cook Inc, Bloomington, Ind) was advanced to the distal aortic arch from the right femoral artery, and an 18F sheath was advanced to the ascending aorta from the RSCA.

Stent grafts for bridging to the descending aorta and brachiocephalic artery (Gore TAG, TG3420, and Gore Excluder contralateral limb, PXC 181200; W. L. Gore & Associates) were then advanced into the DBG main graft and branch graft, respectively, and deployed (Fig 3, *D*). After deployment, balloon touch-up of each aortic stent graft was performed using the kissing balloon technique by using a Gore Tri-Lobe balloon for the main graft and a Gekira 18-mm balloon (Cosmotec, Tokyo, Japan) for the branch graft, while systolic blood pressure was controlled to <50 mm Hg by rapid right ventricular pacing (140 beats/min). The final angiogram showed good flow into the branch graft and complete exclusion of the thoracic aortic aneurysms, with no endoleak (Fig 4).

Extubation was performed 4 hours after the operation, and the patient had an uneventful postoperative course. Postoperative computed tomography angiography at 1 week revealed no endoleak (Fig 5), and the aneurysm showed shrinkage at 6 months postoperatively.

DISCUSSION

The advantage of our new hybrid treatment for extensive aortic aneurysms that include the ascending aorta is that this technique provides an adequate proximal landing zone just above the sinotubular junction with minimal open surgery. Although short-duration CPB and cardiac arrest are required, this procedure provides a reliable proximal landing zone and exclusion of the native aortic wall in the ascending aorta, which is at risk of developing aneurysmal dilatation or dissection. Eggebrecht et al[7] reported that ascending aortic dissection after a hybrid aortic arch procedure is a devastating complication associated with high mortality and opined that it could be due to injury to the aortic wall by the stent graft or to the progression of underlying aortic disease. This suggests that to achieve better long-term outcomes, it should be mandatory to avoid leaving aneurysmal or marginal ascending aorta. From this point of view, the procedure reported here could provide satisfactory long-term durability.

Furthermore, this procedure has the potential to expand its indications when branched stent grafts for aortic

arch aneurysms are introduced into clinical practice. These branched devices could be an attractive treatment option for aortic arch aneurysms; however, they are only practical if an adequate proximal landing zone is provided in the ascending aorta.[8] The insertion of a single vascular graft into the ascending aorta could provide an adequate landing zone just above the sinotubular junction, and complete exclusion of aneurysms could be accomplished by subsequent endovascular repair using branched stent grafts.

Patel et al[4] and Okada et al[9] reported from a cohort who underwent aortic arch repair that prolonged CPB time was an independent risk factor for early mortality. Moreover, DHCA has also been reported to be associated with postoperative neurologic deficits and poor quality of life after conventional open arch repair in high-risk patients.[6,10] In this respect, our new treatment method could be advantageous, particularly for high-risk elderly patients. In this case, 60 minutes of CPB time and 36 minutes of cardiac arrest time were required—considerably shorter than conventional aortic arch replacement, with an average CPB time of 147 to 226 minutes and cardiac arrest time of 85 to 168 minutes.[1,2,4,9]

The limitations of this procedure are as follows:

1. Patients with mural thrombosis or severe calcification in the ascending aorta, which could represent a risk for insertion of a vascular graft, are not eligible.
2. Although the duration is short, CPB and cardiac arrest are still needed during the insertion of the DBG into the ascending aorta.
3. There are some anatomic prerequisites for the use of this procedure. For the DBG to be inserted smoothly into the ascending aorta, the aortic diameter must be at least 40 mm. In addition, the distance from the sinotubular junction to the origin of the brachiocephalic artery must be no less than 4 or 5 cm to provide a sufficient insertion of the DBG. Moreover, to provide a sufficient landing zone for the branch graft, 2 cm is needed from the origin of the brachiocephalic artery to the brachiocephalic bifurcation.

CONCLUSIONS

This newly developed hybrid procedure for extensive aortic aneurysms was performed successfully, without major complications. It provided an adequate proximal landing zone just above the sinotubular junction, with minimal surgery, and could be an attractive hybrid treatment option for extensive aortic aneurysms that include the ascending aorta.

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